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Essay

Mapping the Labyrinth of Scientific Evidence

by
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In *Daubert v. Merrell Dow Pharmaceuticals,*[1] the United States Supreme Court assumed the task of giving lower courts some direction in navigating the labyrinthean corridors that connect law and science. As the lower courts begin to follow this guide, it is clear that the Court has only showed them the gateway to the law-science maze, even though the lower courts are to be its gatekeeper.[2] *Daubert* provided precious little advice on how to successfully resolve the tangled relations between law and science.[3] However, the little guidance *Daubert* does contain provides important clues to a successful blueprint of the law-science labyrinth.

The single most important "guidepost" contained in *Daubert* is the Court's directive to judges to actively evaluate scientific evidence. This does not mean that the Court envisions judges replacing jurors as the ultimate determiners of the weight scientific evidence should re-

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* , Professor of Law, University of California, Hastings College of the Law. I would like to thank my many colleagues who commented on early drafts of this essay. Especially deserving of my gratitude are Margaret Berger, David Kaye, Roger Park, and Eileen Scallen.

1. 113 S. Ct. 2786 (1993).

2. *Id.* at 2798-99.

3. The lack of advice to be found in *Daubert* perhaps is best illustrated by the surplus of commentary seeking to interpret and advance the *Daubert* lesson; this Essay, of course, adds to that surplus. For a representative sample, see Bert Black et al., *Science and the Law in the Wake of* Daubert: *A New Search for Scientific Knowledge,* 72 TEX. L. REV. 715 (1994) (providing a pragmatic account of what separates science from other forms of knowledge); Paul S. Miller et al., Daubert *and the Need for Judicial Scientific Literacy,* 77 JUDICATURE 254 (1994) (discussing the need for scientific literacy of trial courts); Linda Sandstrom Sinnard, Daubert's *Gatekeeper: The Role of the District Judge in Admitting Expert Testimony,* 68 TUL. L. REV. 1457 (1994) (suggesting a theoretical approach to determining reliability to be used when the hypothesis may not be generally accepted); Symposium, *Evidence After the Death of Frye,* 15 CARDOZO L. REV. 1745 (1994).

ceive. Instead the *Daubert* Court understood scientific issues of validity[4] to be integral to determinations of admissibility. Inaccurate scientific evidence lacks legal relevance. The Court placed the initial burden of demonstrating validity on the proponent of the evidence and the initial responsibility for evaluating that validity on the judge. By replacing the general acceptance standard of *Frye v. United States*[5] with the validity standard of *Daubert*, the Court discarded a standard that was deferential to external groups with one that requires judges themselves to make the necessary determination.

The directive to judges, who are now expected to become sophisticated consumers of science, raises a host of questions and potential difficulties. Among the two most salient are: first, what is the scope of this new responsibility? and second, how should this task be implemented as a practical matter? Each of these questions contains numerous subparts, all ripe with unresolved issues. Is the category of science so wide that it encompasses such complex fields as high energy physics and organic chemistry as well as fields such as psychiatry, economics, sociology, and medicine? And although it might be a given that *Daubert* expects judges to be able to distinguish a mean from a mode, does the new standard expect such depth that a judge can distinguish an analysis of variance from a multiple regression analysis or a Restriction Fragment Length Polymorphism from a Polymerase Chain Reaction? The practical application of *Daubert* raises significant issues concerning the principles that the Federal Rules of Evidence generally and the expert testimony rules specifically embrace. The premise in *Daubert* is built primarily on the principle of trustwor-

4. Courts regularly use the scientific concepts of reliability and validity interchangeably, terms that have definite scientific meanings. *See* David L. Faigman, *To Have and Have Not: Assessing the Value of Social Science to Law as Science and Policy,* 38 EMORY L.J. 1005, 1010 n.16 (1989) [hereinafter Faigman, *To Have and Have Not*] (defining reliability and validity and providing an example illustrating the difference). The *Daubert* Court noted this distinction: "[S]cientists typically distinguish between 'validity' (does the principle support what it purports to show?) and 'reliability' (does the application of the principle produce consistent results?)." *Daubert,* 113 S. Ct at 2795 n.9. The Court stated clearly that "validity" is the germane inquiry: "In a case involving scientific evidence, evidentiary reliability will be based upon scientific validity." *Id.*

5. 293 F. 1013 (D.C. Cir. 1923). The often-quoted *Frye* test provides as follows:

> Just when a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognized, and while courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs.

Id. at 1014.

thiness or accuracy. But how do the other principles of the Rules, such as efficiency, unfair prejudice, and, particularly, necessity interact with the *Daubert* premise?

This Essay explores these various questions, and it tries to offer a perspective by which judges might resolve the complicated and difficult issues these questions pose. It is organized around the two questions above, with Section I considering the scope of a judge's responsibility under *Daubert* and Section II examining *Daubert* in light of the general principles of the Rules of Evidence. My central operating premise should be stated clearly at the outset: Only when judges become sophisticated consumers of science will they be able to effectively integrate the lessons of science into the dictates of the law. This Essay considers the level of sophistication that is needed and the composition of the evidentiary framework into which science must be integrated. This framework encompasses both the rules by which trial courts scrutinize expert testimony and the rules by which appellate courts scrutinize trial courts' admissibility decisions.

I. The Scope of a Judge's Responsibility Under *Daubert*

In his concurring opinion in *Daubert,* Chief Justice Rehnquist voiced a common complaint about the competence of judges to understand complex scientific methods and terminology.[6] The majority opinion, in contrast, expressly affirmed its faith in judges' ability to master the basic components of science.[7] However, as the Chief Justice pointed out, he does not question judges' intelligence to master science;[8] rather, his concern seems to be their inability to expend the time and energy that would be necessary to understand the intricacies of science. The issue then shifts from whether judges can be competent to how competent they must be. The degree of expertise required of judges depends largely on the importance of scientific evidence to the legal system. Unfortunately, little research has been conducted on the number of cases that depend on scientific expert testimony.[9] Despite this dearth of research, the popular perception is that science now plays a very significant role in both the civil and criminal justice

6. 113 S. Ct. at 2800 (Rehnquist, C.J., concurring).

7. *Id.* at 2796.

8. *Id.* at 2800.

9. On the more general question of how frequently experts are used, see Samuel R. Gross, *Expert Evidence,* 1991 Wis. L. Rev. 1113, 1119.

systems and this role is likely to increase.[10] If this perception is true, then significant investment in time and energy to learn scientific principles will pay substantial dividends to judges.

A. How Wide Must a Judge's Scientific Knowledge Be?

Some of the reluctance on the part of judges to plunge into the scientific waters must be that this sea is very wide indeed. Even a partial list of scientific specialties having legal relevance would cover several pages of text here. "Scientists" offer opinions on topics ranging from voice spectrography to gas chromatography, from premenstrual syndrome to post-traumatic stress syndrome, and from identification through bitemarks to identification through handwriting. A judge attempting to swim from shore to shore of this sea would finish, at best, exhausted and, at worst and more likely, drown. To stay afloat, must judges develop expertise in all areas of science, or is the expectation and goal more modest?

Daubert does not stand for the lesson that judges should be experts in any one area, much less in all areas, of science. Instead the Court created an approach to scientific evidence that only requires judges to know how to swim, not to actually make the swim across the entire breadth of science. Judges must, therefore, have the basic skills necessary to read and understand scientific methods and to integrate scientific knowledge in their legal decisions. Their skills will be tested in particular cases, but there will be no general competency test.

This approach to knowledge acquisition is not new or revolutionary. In fact, virtually every major law school builds its curriculum around the principle of general competency. Students do not learn the details of the sundry topics taught in the modern college of law. When properly taught, legal education is graduate training that enables students to learn on their own.[11] Law school teaches students the skills, but it is only over a lifetime of practice that those skills are refined through application to concrete and specific cases.

The problem with judges' familiarity with science is not that they do not know whether Bendectin is a teratogen or whether silicon

10. *See, e.g.*, PETER W. HUBER, GALILEO'S REVENGE: JUNK SCIENCE IN THE COURTROOM (1991). Huber's interpretation of the "crisis" in the law-science relationship has been severely criticized. *See, e.g.*, Kenneth J. Chesebro, *Galileo's Retort: Peter Huber's Junk Scholarship*, 42 AM. U. L. REV. 1637, 1726 (1993) (attributing "the prominence of the book and its author to clever public relations, not merit").

11. *See generally* ANTHONY T. KRONMAN, THE LOST LAWYER: FAILING IDEALS OF THE LEGAL PROFESSION (1993).

breast implants cause connective-tissue diseases, but that they do not understand basic principles of epidemiology and statistics, principles which scientists use to study these questions. Reading a scientific report on Bendectin without any training in epidemiology or statistics would be like reading *Palsgraf v. Sidotti* without knowing what proximate cause means. Readers would have a general sense that they know what is going on and that the argument sounds impressive, but ask them to explain or criticize it and you are likely to get little more than a shrugging of shoulders. There has been a good deal of shrugging of shoulders over scientific evidence.

Intertwined with the concern of how wide a judge's knowledge must be is the problem of identifying where the scientific sea begins and ends. Practitioners in disciplines ranging from astrology to astrophysics claim to be "scientists." Just as oceans do not begin and end abruptly, but instead mix with the fresh waters that flow into them, science has no bright line boundaries. There are many bodies of knowledge lying outside the scientific sea or flowing into it that smell distinctly of brine. Indeed, Rule 702 expressly anticipates this problem in determining boundaries, including as within the domain of expert testimony not only "science," but "technical, or other specialized knowledge."[12]

The *Daubert* Court did not discuss the applicability of its holding to the "technical or other specialized knowledge" contemplated by Rule 702. In fact, *Daubert* could be read to apply only to "scientific knowledge," given the Court's heavy reliance on the definition of the word science in both its dictionary sense[13] and its more philosophical sense.[14] Such a reading displays a crabbed interpretation of the Court's opinion as well as a misconstruction of the principles underlying Rule 702.[15]

The purpose of expert testimony under Rule 702 is to "assist the trier of fact" in doing her job. The trier of fact's task is to weigh facts put into evidence. The value of an expert's testimony depends on its factual basis and an expert is not in court to impress upon the jury

12. FED. R. EVID. 702.

13. *Daubert,* 113 S. Ct. at 2795 (citing WEBSTER'S THIRD NEW INTERNATIONAL DICTIONARY 1252 (1986) for the definition of "knowledge").

14. *Id.* at 2796-97 (citing Professor Karl Popper's principle of "falsifiability" as the hallmark of scientific statements, *in* CONJECTURES AND REFUTATIONS: THE GROWTH OF SCIENTIFIC KNOWLEDGE 37 (5th ed. 1989)).

15. *See* David L. Faigman, *The Evidentiary Status of Social Science Under Daubert: Is It "Scientific," "Technical" or "Other" Knowledge?*, PSYCHOLOGY, PUBLIC POLICY AND LAW (forthcoming 1995).

some normative position favored by the expert's employer.[16] Rule 702 is designed to regulate the scope of expert testimony, and it fully contemplates that sometimes nonscientific disciplines will have access to facts that might assist jurors.

Although the scientific method continues to attract its share of detractors and skeptics, the significant advances in science and technology in the twentieth century illustrate the power of that method. In identifying, predicting, and controlling the world around us, science is by far the most powerful intellectual technique known. In fact, the scientific method is so powerful that disciplines not ideally suited for its use have from time to time sought its mantle, including history, philosophy, and the law. However, the recognition of the power of science should not be interpreted as blind allegiance to its dictates. Science provides no assistance over broad and profoundly important areas of human concern, most particularly that of values. Moreover, science is slow, even plodding, and it often requires ideal conditions that rarely exist or studies only small numbers of variables that limit the ability to generalize any findings. The questions scientists ask and the methods they choose to study them are invariably infused with the researchers' implicit beliefs, both normative and empirical.[17]

These limitations on science are implicit in Rule 702's recognition that "technical or other specialized knowledge" should sometimes be permitted to form the foundation for expert opinion. But given the power of the scientific method, these alternatives should suffice only where science provides too little assistance or so much assistance that it amounts to overkill. In general, two problems recur that limit science's usefulness to the law. The first involves factual questions that do not lend themselves to the scientific method because they are either inherently not amenable to it or they are so complex that scientists do not yet have the tools to study them; the second concerns matters so elementary that nonscientists' extensive experience with them should be sufficient for the law's purposes.

The scientific method assumes the replicability of physical phenomena.[18] But not all facts repeat themselves. The classic example of facts that are intensively studied but are not replicable are historical events. Despite Santayana's caution that "[t]hose who do not remem-

16. *See generally* Faigman, *To Have and Have Not, supra* note 4, at 1074-79.

17. Faigman, *To Have and Have Not, supra* note 4, at 1026-39.

18. *See generally* ERNEST NAGEL, THE STRUCTURE OF SCIENCE: PROBLEMS IN THE LOGIC OF SCIENTIFIC EXPLANATION 29-46 (1979).

ber the past are doomed to relive it,"[19] understanding the present or predicting the future from historical "facts" is a perilous business.[20] Frequently, history is highly relevant to legal decision making and the law must depend on a nonscientific method for gathering that information.[21] This is not to say that the law should not demand the best methods that historians have in their arsenal—many of which are highly sophisticated techniques that rival science for eliminating alternative hypotheses[22]—only that those methods are not "scientific." But the lesson is clear: Judges cannot insist on their preconceived notions of appropriate methods, but instead must become acquainted well enough with the methods of the fields they rely on to recognize findings worthy of the law's attention.

Some facts of relevance to the law involve matters so complex that scientists have not, and perhaps can never, isolate the phenomenon sufficiently to study it in depth. Indeed, many of the factual questions the law raises about human behavior are examples of complex phenomena not easily studied. For example, the psychological effects of extreme stress present formidable difficulties for psychologists. To recognize that many reputedly scientific matters remain on the perimeter of scientific skill should not lead to scientific nihilism.[23] Just as with the study of history, noted above, the proper response to empirical complexity should not be to call in the witchdoctor for a magic spell, but rather to demand the best science available and remain aware of its limitations. For instance, although meteorologists are not absolutely accurate in predicting as complex a phenomenon as the

19. GEORGE SANTAYANA, THE LIFE OF REASON (1953).

20. Henry Adams nicely captured this lesson: "The historian must not try to know what is truth, if he values his honesty; for, if he cares for his truths, he is certain to falsify his facts." THE INTERNATIONAL THESAURUS OF QUOTATIONS 279 (Rhoda Thomas Tripp ed., 1987) (citing HENRY ADAMS, THE EDUCATION OF HENRY ADAMS 37 (1907)).

21. A classic instance of history's relevance, although not specifically involving an "adjudicative fact," occurred in the desegregation litigation of *Brown v. Board of Education*. An intermediate court asked the two sides for further argument on the intention of the Framers of the Fourteenth Amendment regarding public school segregation. Brown v. Board of Educ., 345 U.S. 972 (1953) (miscellaneous orders). Volumes of historical scholarship were offered by the litigants. However, the historians could not reach consensus on the matter. The Court later dismissed these materials, stating, "At best, they are inconclusive." Brown v. Board of Educ., 347 U.S. 483, 489 (1954).

22. *Cf.* William E. Nelson, *History and Neutrality in Constitutional Adjudication*, 72 VA. L. REV. 1237, 1245, 1250-56 (1986) (explaining and encouraging the use of methods of neutral principles and interpretivism as effective means of resolving constitutional issues).

23. The so-called "hard sciences" also raise questions that might never be amenable to testing. *See, e.g.*, STEPHEN W. HAWKING, A BRIEF HISTORY OF TIME: FROM THE BIG BANG TO BLACK HOLES 74-75 (1988) (discussing the physical impossibility of building a particle accelerator large enough to test grand unified theories of the universe directly).

weather, they far out perform their witchdoctor competitors.[24] The law must be sophisticated enough to appreciate the differences in the methodological tools used by meteorologists and those wielded by the authors of the Farmers Almanac.

At the other extreme, the law also depends on facts that are readily known through extensive study or experience, but with which triers of fact are likely to have little familiarity. A common example of specialized knowledge contemplated by Rule 702 is that held by mechanics. The law permits auto mechanics to testify because their knowledge is thought to be readily obtainable so long as they spent enough time studying the matter.[25] But recognizing that some facts can be known without the elaborate methods of science does not refute the relevance of the scientific method; it only indicates that sometimes that level of expertise is not necessary. The workings of a carburetor are no less susceptible to scientific understanding than the workings of a supercollider, the law merely assumes that an experienced mechanic can accurately describe the former, but only a scientist can accurately describe the latter. This aspect of Rule 702 is essentially an efficiency principle related to the necessity principle discussed in the next Section. In short, Rule 702 implicitly relaxes the requirement for a scientific demonstration when a less rigorous, less time consuming, and less expensive alternative would provide sufficiently accurate information. When the subject of expert testimony is straightforward, the law dispenses with the requirement of scientific proof because it is excessive, not because it is unavailable.

B. How Deep Must a Judge's Scientific Knowledge Be?

Although there are numerous applications of science in the law, the categories of expertise are fairly limited. Whereas psychology seems pervasive, cosmology appears rarely in published opinions.[26] The principal skill that most, if not all, legal uses of science share is knowledge of descriptive and inferential statistics. In fact, in light of the numerous occasions in which statistics are relied upon in everyday

24. *See generally* JAMES GLEICK, CHAOS: MAKING A NEW SCIENCE 7 (1987) ("Predictability is one thing in a cloud chamber where two particles collide at the end of a race around an accelerator. It is something else altogether in the simplest tub of roiling fluid, or in the earth's weather, or in the human brain.").

25. *See generally* MCCORMICK ON EVIDENCE §13, at 21-22 (John William Strong ed., 4th ed. 1992) (stating the expert's contribution is the power to draw inferences from the facts that a jury would not be competent to draw).

26. A recent Westlaw search uncovered eight cases in the United States in which the word "cosmology" appeared, none of which involved application of that science.

legal practice, it is a little surprising that law schools do not require an introductory course in the subject. In addition to statistics, most legal uses of science depend on fairly straightforward research methodologies, including animal studies, case studies, epidemiological studies, quasi-experimental designs, and controlled experiments. With one course in statistics and one in research methodology, the average judge would have little difficulty reading reports of research in such diverse areas as trademark infringement surveys, predictions of dangerousness, repressed memories, and electromagnetic radiation. With little additional study, DNA profiling and gas chromatography could be readily understood.

In responding to the query, how deep must a judge's knowledge be?, some perspective on the question must be maintained. In a sense, the best answer is that a judge should obtain as deep and profound an understanding as is possible under the circumstances. Judges must learn the methods of science not to resolve scientific debates, but rather to resolve legal debates.[27] In large measure, *Daubert's* replacement of *Frye* anticipates that there will be many cases in which the research lacks general consensus in its field, but it is accurate enough to assist the trial process. Of course, if scientists are unable to agree on the validity of the research, we should hesitate before asking judges (or juries, for that matter) to settle the matter. Judges provide a screening function to determine whether the science is sufficiently valid to assist the trier of fact. Judges thus should exclude bad science in order to control the flow of confusing, misleading, erroneous, prejudicial, or useless information to the jury. Their job is to protect the integrity of the trial process.

As judges begin to assume the task of evaluating science substantively, they can be expected to seek training in basic statistics and research methodology. In fact, since *Daubert* was decided, many professional education programs for federal and state judges have focused on scientific topics.[28] In addition, the market can be expected to respond, and indeed already has responded, to this need for infor-

27. *See Daubert*, 113 S. Ct. at 2798-99 ("We recognize that in practice, a gatekeeping role for the judge, no matter how flexible, inevitably on occasion will prevent the jury from learning of authentic insights and innovations. That, nevertheless, is the balance that is struck by Rules of Evidence designed not for the exhaustive search for cosmic understanding but for the particularized resolution of legal disputes.").

28. For example, the Federal Judicial Center recently has held programs on scientific evidence in New Orleans (Dec. 12-13, 1994) and San Francisco (Jan. 23-24, 1995).

mation.[29] Therefore, with a willingness to learn and a sense of adventure, judges can introduce themselves to a world of intellectual rigor and aesthetic symmetry and avoid a world of unbounded speculation and logical anarchy. However, judges will soon find that the difficult part lies not in learning what science has to offer, but in integrating those offerings into a legal framework that is not altogether suited for the task. The perplexing question of how to integrate science into the law is the topic of the next Section.

II. Implementing *Daubert*

The *Daubert* opinion is, with regard to evidentiary foundations, incomplete. It is one-dimensional in that it relies on only one principle, validity, to set forth the standard for admitting scientific evidence. In evidentiary terms, scientific validity relates to the trustworthiness or accuracy component inherent in the Federal Rules' structure. Simultaneously, the opinion explicitly mandates that judges use Rule 403 to exclude scientific evidence that, while valid and relevant, nonetheless would substantially and unfairly prejudice the opponent or waste the court's time.[30] Yet, somewhat surprisingly, the second major foundational principle that joins trustworthiness to define many provisions of the Federal Rules is missing from the Court's interpretation of Rule 702. In many other evidentiary contexts, necessity plays a significant role in determining the admissibility of evidence. It is all the more surprising that necessity plays no part in Rule 702 because the intersection of science and law would seem especially well suited to this principle.

In a wide range of evidentiary contexts, the Rules apply the formula that the sum of trustworthiness and necessity determines admissibility. The most notable examples, and the ones most pertinent to the present discussion, are the numerous exceptions to the hearsay

29. Two projects dedicated to this educational need will be published this year. The Federal Judicial Center is publishing a manual that will provide federal judges with an overview of methodologies in such areas as epidemiology, toxicology, multiple regression analysis, and others. And in a project that will complement the FJC report, West Publishing Company is publishing a comprehensive two-volume manual that will provide in-depth analysis of more than 40 different areas of science, with the principal chapters written by renowned scientists, covering such diverse areas as survey research, repressed memories, battered woman syndrome, DNA profiling, breast implants, soil analysis, and so on. WEST'S COMPANION TO SCIENTIFIC EVIDENCE (David L. Faigman et al. eds., forthcoming 1995).

30. *Daubert*, 113 S. Ct. at 2798.

rule.[31] For example, Rule 803 does not require that the declarant be unavailable because the exceptions it contains are deemed sufficiently trustworthy without a showing of special need; Rule 804, in contrast, requires a showing that the declarant is unavailable because the statements permitted under that rule are considered less trustworthy than those of Rule 803. Therefore, as the need for the evidence increases, the demand for trustworthiness decreases, and vice versa.[32]

On its face, Rule 702 does not express the kind of necessity principle discussed in this Section. Perhaps a more liberal and enlightened reading of the Federal Rules than is currently in fashion could find the principle implicit in the Rules' text. I take no position here on the proper school of interpretation to follow when reading the Federal Rules and leave that difficult task to others who have assumed it.[33] This Section argues that Rule 702 would allow judges to better integrate science into the trial process if it contained a necessity principle.

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31. The most obvious other example is the Best Evidence Rule and, specifically, Rule 1004, which permits nonoriginal documents if certain conditions associated with special need are met. In fact, Rule 403, the bedrock upon which the Rules are built, contains a negative necessity principle by providing for exclusion of relevant evidence that wastes time or needlessly presents cumulative evidence. One more example is Rule 611(c): "Leading questions should not be used on the direct examination of a witness except as may be necessary to develop the witness's testimony."

32. The Advisory Committee's Note to Rule 804 is explicit about this calculation:

> Rule 803 . . . is based upon the assumption that a hearsay statement falling within one of its exceptions possesses qualities which justify the conclusion that whether the declarant is available or unavailable is not a relevant factor in determining admissibility. The instant rule proceeds on a different theory: hearsay which admittedly is not equal in quality to testimony of the declarant on the stand may nevertheless be admitted if the declarant is unavailable and if his statement meets a specified standard. The rule expresses preferences: testimony given on the stand in person is preferred over hearsay, and hearsay, if of the specified quality, is preferred over complete loss of the declarant.

For more extensive and critical analyses of the trustworthiness/necessity relationship in the hearsay rules, see Michael L. Siegel, *Rationalizing Hearsay: A Proposal For A Best Evidence Hearsay Rule*, 72 B.U. L. Rev. 893, 946-48 (1992) (arguing that, in reality, unnecessary and potentially unreliable hearsay statements are routinely admitted); Eleanor Swift, *A Foundation Fact Approach to Hearsay*, 75 Cal. L. Rev. 1339, 1371 n.96 (1987) (suggesting that the necessity "principle" may only serve expediency and fails to reflect true necessity).

33. *See, e.g.*, Randolph N. Jonakait, *The Supreme Court, Plain Meaning, and the Changed Rules of Evidence*, 68 Tex. L. Rev. 745 (1990) (warning that application of the plain meaning standard will have a negative impact on evidence law and will fail to satisfy policy goals); Eileen A. Scallen, *Classical Rhetoric, Practical Reasoning and the Law of Evidence*, Am. U. L. Rev. (forthcoming 1995) (arguing that the best approach to construction of the Evidence Rules is practical reasoning); Glen Weissenberger, *The Supreme Court and the Interpretation of the Federal Rules of Evidence*, 53 Ohio St. L.J. 1307 (1992) (arguing that application of the doctrine of legislative intent is misplaced in interpretation of the Federal Rules of Evidence).

Therefore, if the Rules are thought not to contain such a principle, then they should be amended to include it; and if the Rules can be construed to contain that principle, then judges need to begin developing that principle in the light of *Daubert.*

A. Incorporating the Necessity Principle in Practice

Perhaps the basic problem endemic in the integration of law and science is that the law's search for truth is time-bound, whereas science strives for truths unencumbered by limitations periods and crowded dockets. For instance, a plaintiff who brought suit in 1960 claiming that exposure to asbestos caused her illness might have lost because the research studies demonstrating the health hazards of asbestos were not yet adequately known; the plaintiff who sued after the research was reported is thus able to prevail not because her situation is different from her predecessor's, but only because her timing was better.[34] The law works under extraordinary time pressure and is limited by the ignorance of the age. The law desires truth, but realistically settles for justice and fairness. Fairness in particular mandates that the evidentiary rules for scientific evidence include a necessity component.

The necessity principle speaks to a host of limitations inherent in the law's need for science "now," as well as the limitations in science's ability to answer the complex questions the law tends to ask of it. A principal difference between law and science is that the law must make decisions today, even if that means resolving a problem with imperfect or with no information. Science usually can defer judgment until sufficient data have been collected. The timelessness of science undermines the timeliness of the law. When judges look to science and find an incomplete picture, they should decide admissibility on the basis of a combination of scientific merit and jurisprudential need.

Adding a necessity principle to expert testimony rules would permit judges to make more flexible and subtler judgments regarding the

34. The necessity principle developed in this Essay is closely related to the obstacle created by statutes of limitation. If limitation periods were relaxed pending the completion of significant empirical research, necessity would not be an important factor in the evidentiary context. *See generally* Michael D. Green, *The Paradox of Statutes of Limitations in Toxic Substances Litigation,* 76 CAL. L. REV. 965, 970 (1988) (arguing for the abolishment of statutes of limitations in toxic substance litigation to improve the quality of evidence and "delaying litigation until scientific understanding of causation can be more fully developed"); Francis E. McGovern, *Resolving Mature Mass Tort Litigation,* 69 B.U. L. REV. 659, 668 (1989) (discussing asbestos defendants state-of-the-art defense based on the inability to warn product users of hazards of which defendants were unaware at the time).

state of scientific research. For instance, it would permit a judge to say that though the research so far conducted is not as sound or as extensive as we might desire or expect in the future, it is admissible because of special need. At the start of most ultimately successful research programs there are studies that are "promising" or that indicate that further research is likely to demonstrate substantial findings. If the law waits for this subsequent work to be conducted, some parties will be disadvantaged by not having the evidence available to them. At the same time, the necessity principle will allow judges to exclude scientific evidence when those early findings failed to fulfill their promise or were never pursued with any rigor.

To be sure, admitting evidence that has not yet matured poses many dangers. A principal danger is that subsequent research will fail to confirm the promise of the early work. But there is no functional difference between making a mistake to admit evidence and making a mistake to exclude evidence. Only the identity of the injured party changes. The costs associated with making these errors depend on the circumstances of the particular context. This is a subtle judgment that presents a substantial challenge if faithfully carried out. It means that judges would do an explicit evaluation of the costs associated with making a mistake in the legal context in which the science is offered. For instance, early in the Bendectin litigation, plaintiffs pursued causes of action against Merrell Dow on the basis of only a few studies examining the teratogenic effect of the drug.[35] At that time, the "reality" of Bendectin was uncertain. Merrell Dow's position was that to permit these suits to go forward would force it to remove a beneficial drug from the marketplace and, possibly, deter it and other companies from high-risk (and high-benefit) drug production.[36] Plaintiffs argued that to not permit them the opportunity to introduce the limited empirical evidence available would forever foreclose them from recovering for their injuries. Courts were thus presented with a choice between two types of error. They could have excluded the expert testimony when, in fact, the drug caused birth defects, or they could have admitted the expert testimony when, in fact, the drug did not cause birth defects. In determining the "admissibility" of the research, the

35. For a thorough examination of the evolution of a toxic tort litigation, see Joseph Sanders, *The Bendectin Litigation: A Case Study in the Life Cycle of Mass Torts,* 43 HASTINGS L.J. 301, 318, 350-58 (1992).

36. In fact, Merrell Dow "voluntarily withdrew Bendectin from the market in 1983" because of "the increasing number of lawsuits and the decline in sales caused by negative publicity." *Id.* at 319.

judge must "balance" the costs of making one or another error under conditions of uncertainty.[37]

Although in one sense science is "timeless," as a practical matter scientists regularly must decide whether to accept or reject particular theories or hypotheses. In making this judgment, two types of error are possible. A researcher might conclude that the factor of interest had an effect when it did not (type I error); or she might conclude that the factor of interest had no effect when it did (type II error). Scientists have adopted certain conventions to minimize an experimenter's independent judgment in drawing conclusions from data. In particular, the much discussed convention of a .05 probability of confidence restricts researchers to the relatively conservative risk of a five percent chance of making type I errors (assuming that the null hypotheses is true).[38] But this is only a standard and the costs associated with either type of error in particular cases might lead scientists to change it. Sometimes, researchers might wish to lessen the risk of making a type I error by adopting a more conservative level of confidence, say one out of one hundred (.01); less concern with making a type I error may lead a researcher to adopt a less conservative level of confidence, possibly ten out of one hundred (.10).[39]

In deciding whether to admit scientific evidence into court, judges confront the same possibilities of error as scientists. The trial court makes what might be termed a type I error when it admits scientific evidence that is invalid; and it makes a type II error when it excludes evidence that is valid. The fact that the jury ultimately decides how much weight to attribute to the science does not alter this predicament. First of all, juries should only hear relevant evidence and scientifically invalid findings are irrelevant. There is little reason to believe, and some to doubt, that juries have the scientific sophistica-

37. The balance of costs associated with admitting certain kinds of scientific evidence would ultimately be determined by appellate courts and thus would be settled across jurisdictions.

38. *See* DAVID BARNES, STATISTICS AS PROOF: FUNDAMENTALS OF QUANTITATIVE EVIDENCE 237-38 (1983) (comparing two general rules, the Supreme Court's indication of "two to three standard deviations" and others courts' use of 95% for discrimination cases); D. HINKLE ET AL., APPLIED STATISTICS FOR THE BEHAVIORAL SCIENCES 159 (1979).

39. One standard statistics textbook suggests that researchers should find an effect when the p level is greater than .01 (*i.e.*, probability of making a type I error is less than one percent) but not when it is greater than .10. When the *p* level is in between, the significance is borderline, and any conclusions should be viewed accordingly. DAVID G. KLEINBAUM & LAWRENCE L. KUPPER, APPLIED REGRESSION ANALYSIS AND OTHER MULTIVARIABLE METHODS 29 (2d ed. 1988). *See generally* Faigman, *Have and Have Not*, *supra* note 4, at 1037 n.110 (contrasting research on drugs thought to treat AIDS from those thought to have cosmetic benefits in regard to what decision rule to apply).

tion to correct judicial errors. Moreover, even if jurors are more scientifically literate than judges, the predicament of the inevitability of error is endemic to the scientific enterprise. The principal concern, regardless of whether the judge or jury decides the matter, is which type of error is best avoided. Inherent in this determination is the necessity principle, which is a function of the state of the art of the science in light of the value considerations present in the pending matter.

The necessity principle requires judges to take into account the state of the science in light of the nature of the legal issues involved. Science can no longer be appraised in simplistic categorical terms as accurate or inaccurate. Like other matters with which judges are quite familiar, scientific statements contain error rates that qualify their value. At the same time, different costs are associated with making mistakes in different legal contexts. For instance, judges might demand greater accuracy in psychological assessments of dangerousness in capital sentencing hearings than in parole hearings. It might be that psychologists are slightly better than chance in predicting dangerousness, but the irreducible and substantial prospect of false-positive predictions might compel a judge to exclude this evidence as posing too great a danger in capital cases.

A sophisticated appreciation of scientific error rates might lead to what many legal observers would consider paradoxical outcomes. Specifically, it modifies substantially the principle of stare decisis. For example, a plaintiff who brings suit before the science has fully matured might be permitted to introduce the little research available because of jurisprudential need and because it provides the best available factual resource. However, in time the research might fail to fulfill the promise of the early studies, and experts will no longer be permitted to testify. The necessity principle thus turns current practice almost on its head. Today, in theory at least, early plaintiffs cannot introduce immature scientific research no matter how urgent the need; plaintiffs filing suit later are expected to offer only mature research results.

At first glance, the necessity standard contains the potential for producing disincentives to conducting the serious research needed to truly test experimental hypotheses. Much "scientific" expert testimony is more the product of advocacy positions than observation or experiment. If early hypotheses are permitted, then these expert-advocates might be disinclined to seriously test their theories. This result would be the exact opposite of what good science and the *Daubert*

Court mandate. Under the necessity principle, scientists would not be permitted to rest on their early research with the expectation that the law will continue to permit it to be presented to the trier of fact. A basic component of the necessity principle is the judge's appreciation of the nature of the scientific enterprise. Specifically, judges must factor into their admissibility determinations both the opportunity and the difficulty of doing the sort of research on which the expert seeks to report. A basic tenet of the scientific method is that hypotheses will be rigorously tested, however promising the early findings.

One illustration is the history of research on the battered woman syndrome. In 1979 Lenore Walker posited the hypothesis that women who have been victims of long-term abusive relationships suffer from a condition Walker termed "battered woman syndrome."[40] Consistent with this hypothesis, Walker argued, women who suffer from battered woman syndrome and kill their batterers might be justified in doing so despite the fact that the circumstances surrounding the killing appear inconsistent with traditional notions of self-defense. The two main components of Walker's argument are the cycle theory and learned helplessness.[41] The syndrome theory was originally based upon Walker's clinical experience with 120 women;[42] at that time, however, it had not been the subject of an extensive or rigorous research project. Subsequently, in 1984, Walker published a book re-

40. LENORE WALKER, THE BATTERED WOMAN 31-77 (1979) (describing the common characteristics of the battered woman, the men who batter, the psychosocial theory of learned helplessness, and the cycle theory of violence) [hereinafter BATTERED WOMAN].

41. The cycle theory purports to describe three distinct phases of the typical battering relationship. A "tension building phase" erupts into an "acute battering incident," which is in turn followed by "loving contrition." *Id.* at 55-70. According to the cycle theory, the battered woman is reduced to a state of fear and anxiety during the first two phases of the cycle, and her perception of danger extends beyond the time of the battering episodes themselves.

To explain why a woman in a "constant state of fear" does not leave the battering relationship, battered women defendants invoke Walker's adaptation of Martin Seligman's "learned helplessness" theory. Martin E.P. Seligman et al., *Alleviation of Learned Helplessness in the Dog*, 73 J. ABNORMAL PSYCHOL. 256 (1968). Seligman and his colleagues found that laboratory dogs, after being subjected to repeated shocks over which they had no control, "learned" that they were helpless. When subsequently introduced to an escapable situation, the dogs failed to escape. Seligman generalized this phenomenon to depression in humans. MARTIN SELIGMAN, HELPLESSNESS: ON DEPRESSION, DEVELOPMENT, AND DEATH (1975). Applying this theory to the problem of battered women, Walker explains that "the women's experiences . . . of their attempts to control the violence would, over time, produce learned helplessness and depression as the 'repeated batterings, like electrical shocks, diminish the woman's motivation to respond.'" LENORE WALKER, THE BATTERED WOMAN SYNDROME 87 (1984) [hereinafter BATTERED WOMAN SYNDROME] (quoting BATTERED WOMAN, *supra* note 40, at 49).

42. BATTERED WOMAN, *supra* note 40, at xiii.

porting the first extensive study of the syndrome, a project funded by the National Institute of Mental Health and involving more than 400 women.[43]

Incorporating the necessity principle into *Daubert's* framework, a judge should review the research history of battered woman syndrome with great care and a critical eye. In 1979 the hypothesis was novel and for that reason alone had little empirical support. Nonetheless, the theory was supported by clinicians who had experience with battered women and moreover conformed to a common sense view of what might be the outcome of violent relationships. Because criminal defendants were advancing this scientific theory, the prejudicial effect was not as great as if the prosecution had been the proponent of the evidence. Although it is a close judgment, a rational judge in 1979 might very well have been inclined to admit the expert testimony on battered woman syndrome.

By 1984 the scientific context had changed. As judges should expect, the research offered five years after the theory's inception went significantly beyond what was initially available. Unfortunately, the work conducted in those five years was criticized as particularly inferior.[44] The necessity principle requires that judges evaluate scientists' work given their opportunity to test their hypotheses, and a judge seriously reviewing the research in 1984 would have been quite disappointed with the tests done on the original hypothesis. The 1984 research report failed to fulfill the promise of the earlier work primarily by failing to adhere to some of the most basic dictates of the scientific method.[45]

To be sure, not all scientific questions are easily studied and the necessity principle mandates that judges factor in the difficulty of studying the hypothesis of interest. In fact, the battered woman syndrome is a particularly good example of a social phenomenon that is difficult to test. For obvious reasons, psychologists cannot use con-

43. BATTERED WOMAN SYNDROME, *supra* note 41, at 1.

44. For criticisms, see David L. Faigman, Note, *The Battered Woman Syndrome and Self-Defense: A Legal and Empirical Dissent*, 72 VA. L. REV. 619 (1986) (questioning the validity of the research on battered woman syndrome and arguing that expert testimony should not be admitted) [hereinafter Faigman Note]; *see also* James R. Acker & Hans Toch, *Battered Women, Straw Men, and Expert Testimony: A Comment on* State v. Kelly, 21 CRIM. L. BULL. 125 (1985) (arguing matters covered in the testimony are not "beyond the ken" of the average juror and its admission diverts attention from other logically relevant facts).

45. *See* Faigman, *supra* note 44, at 636-43 (discussing a variety of significant flaws in the research testing the cycle theory and the application of learned helplessness to battered women who kill).

trolled experiments to study the effects of violence. But this difficulty does not mean that it is impossible to study the effects of violence, nor does it excuse poorly designed research. Judges, no less than scientists, should expect that, given sufficient time and resources, psychologists will test their hypotheses with the best tools available.

Strictly speaking, the law's "need" for scientific evidence is not likely to decrease substantially as time passes. The law's need for information on the effects of domestic violence in the absence of better research remains. Incorporation of the necessity principle forces judges to recognize the process of scientific advancement. Scientists' failure to pursue rigorous testing of a hypothesis should lead to increased doubt about the accuracy of the hypothesis. For example, early in the debate over cold fusion, scientists and laypersons were willing to give B. Stanley Pons and Martin Fleischmann the benefit of the doubt that they had created fusion at room temperature in Utah based largely on their impressive qualifications.[46] As time passed and they continued to delay a public demonstration of their results, doubts about cold fusion's validity grew. Although at no time would cold fusion have met the *Daubert* test because it was never adequately tested,[47] this history contains an important lesson: science embodies a developmental nature that demands extensive, exhaustive and continuing critical examinations of its tenets. Science thus must evolve; the law must come to understand this nature and demand that scientists adhere to it.

The necessity principle requires judges to incorporate the complexity of research and the inherent difficulty of fully testing some scientific theories. In every scientific field, from physics to psychology, there are hypotheses that defy direct observation or straightforward tests. However, our inability to "see" an electron, for example, does not undermine a rigorous examination of its existence, nature, and form. Difficult and complex theories require more imaginative research designs. One of the basic lessons of *Daubert* should not be lost: *Daubert* exhorts scientists to do good science and expects them to be scientists first and expert witnesses (and advocates) second.

46. For an excellent history of the cold fusion debacle, see GARY TAUBES, BAD SCIENCE: THE SHORT LIFE AND WEIRD TIMES OF COLD FUSION (1993).

47. Although Pons and Fleischmann "tested" the hypothesis, their tests were plainly inadequate. Moreover, they failed to publish their work in a peer reviewed journal and there was no general acceptance of their theory. *Id.* at 53-66.

B. The Challenge and Peril of the Necessity Principle

As the previous discussion indicates, successful use of the necessity principle depends on judges' adequate understanding of scientific techniques. However, this understanding cannot be limited to trial court judges because appellate judges have an integral role to play in the process as well. In fact, because the necessity principle turns stare decisis almost on its head, the process requires a dynamic dialogue between trial and appellate judges. This Section begins by examining the process by which trial and appellate judges should resolve issues of scientific evidence. Finally, this Section concludes with a warning concerning the dangers inherent in using a necessity standard without a sophisticated appreciation of the science involved.

(1) Daubert *and Appellate Review: The Challenge of the Necessity Principle*

The *Daubert* Court did not address the issue of the appropriate degree of appellate review of a trial court's determination concerning validity under Rule 104(a). Although appellate courts are typically deferential to lower court's findings of fact, good reasons exist to modify that approach in the context of scientific evidence. Unlike virtually all other preliminary factual questions made under Rule 104(a), a large component of the decision surrounding scientific evidence transcends individual cases. Whether Bendectin is a teratogen, electromagnetic fields contribute to childhood leukemia, smoking causes cancer, procedures for DNA profiling are valid and reliable, and others are issues that are similarly presented across jurisdictions.[48] Appellate courts conducting an independent substantive review of the science can contribute substantially to the process of settling these matters.

In the usual application of Rule 104(a), trial courts must make a context-specific factual determination. For instance, trial courts must find, by a preponderance of evidence, that a conspiracy existed before permitting evidence under the exclusion for statements made by a coconspirator;[49] and the trial court must similarly find that a statement

48. These issues all fall into the category that Professors Monahan and Walker labeled "social frameworks." *See* Laurens Walker & John Monahan, *Social Frameworks: A New Use of Social Science in Law,* 73 VA. L. REV. 559, 563-70 (1987). The authors describe an emerging use of social science in law in which empirical information is offered to provide a background context for deciding factual issues crucial to the resolution of a specific case.

49. Bourjaily v. United States, 483 U.S. 171 (1987). The trial court must also find, under Rule 801(d)(2)(E), that the statement was made "during the course and in furtherance of the conspiracy."

was made under a belief of impending death before permitting evidence under the exception for dying declarations.[50] Because these facts are specific to the case before the judge and do not repeat themselves in the same form in other cases, substantial deference to the judge as fact finder logically flows out of the judge's close proximity to the matter. When the preliminary facts are not case specific, logic demands little or no deference to the trial court's findings.

Scientific evidence reflects a more complicated structure than the ordinary preliminary fact.[51] At least three levels of science must be accounted for in the admissibility determination. First is "the theory or principle that provides authority for the conclusions that are drawn from the data."[52] An example of this abstract theoretical level of science is the hypothesis that each person's DNA is unique and uniquely defines that individual. The second level is "the general technique or procedure that produces the data."[53] Continuing the DNA example, this level is represented by the laboratory procedures developed to extract and study DNA. The final level is the most concrete: "the specific practices used to obtain the data."[54] Completing the DNA example, this level concerns the laboratory procedures used to "match" the forensic DNA sample with the known sample in the particular case. The value of scientific evidence, both in terms of admissibility and weight, depends on all three levels of scientific investigation.

The inherent structure of science should lead to a process of appellate review whereby trial court findings of fact at the first two levels of science, the theory and general procedure levels, are reviewed on a de novo standard. Because these levels of scientific inquiry do not involve the special circumstances of individual cases, appellate courts are able to evaluate the research at least as well as lower courts. In fact, given the sometimes complex nature of scientific evidence, appellate courts' greater opportunity to consider these matters should give them a better vantage point from which to evaluate the science. The third and most concrete level is case specific and should be left to the broad discretion of the trial court.

50. *See generally* McCORMICK ON EVIDENCE, *supra* note 25, at 523-24. In applying Rule 804(b)(2), the court must also find that the declarant is unavailable under 804(a). *Id.*

51. This analysis of the levels of science is explored in greater depth in David L. Faigman et al., *Check Your Crystal Ball at the Courthouse Door, Please: Exploring the Past, Understanding the Present, and Worrying About the Future of Scientific Evidence*, 15 CARDOZO L. REV. 1799, 1825-34 (1994).

52. William A. Thomas, *Some Observations by a Scientist*, 115 F.R.D. 142, 144 (1986).

53. *Id.*

54. *Id.*

Although de novo appellate review of the scientific theory and the technique or procedure is probably mandated solely on the basis of the structure of scientific inquiry,[55] inclusion of a necessity principle to the rules governing the admissibility of expert testimony is entirely consistent with, and indeed makes more emphatic, this mode of appellate review. The basic insight underlying the necessity principle is that when calculating whether scientific findings should be used, courts should take into account the likelihood that the science is wrong given the context in which it is to be introduced. This calculation blends a sophisticated understanding of the science with a broad appreciation for the policy choices that must be made in particular contexts.

Across the entire scientific spectrum, decisions concerning the admissibility of particular applications of science present complex policy judgments. Use of polygraph tests in criminal trials, for example, implicate a defendant's right to a fair trial. Rape trauma syndrome also raises fair trial concerns when used by prosecutors and raises concerns over impeaching the character of rape complainants when used by the defense. Scientific evidence in mass toxic tort cases, such as asbestos and lead, raise concerns about the most efficient administration of the civil justice system. The list is virtually without end.

Appellate courts are uniquely situated to understand more than just the science underlying expert testimony; their vantage point allows them to fully comprehend the broad policy implications associated with admissibility determinations. Consider the example of DNA profiling, one of the most scientifically complex and legally important instances of expert testimony confronting the courts today. A principal controversy surrounding DNA concerns the presence of subgroups within a general population structure.[56] The effect that subgroups have on the statistical assumptions that go into promulgating probability estimates for DNA "matches" remains controversial. It is clear that the existence of subpopulations affect these estimates, but how much they do,[57] and what is to be done about them is less clear. The general topic of "correcting" possible subpopulation error is too

55. *See* Faigman et al., *supra* note 51, at 1820-22 (quoting Daubert v. Merrell Dow Pharm., Inc., 951 F.2d 1128, 1130 (9th Cir. 1991) and advocating the de novo standard of review of scientific information to avoid inconsistent treatment of similarly situated claims).

56. *See* David H. Kaye, *DNA Evidence: Probability, Population Genetics, and the Courts,* 7 HARV. J. L. & TECH. 101, 127-28 (1993).

57. *Id.* at 128 ("At present, it is doubtful that population structure makes much of a difference.").

expansive to discuss fully here.[58] However, one aspect of this issue nicely illustrates the dynamic between trial and appellate courts.

What approach should courts require experts to employ when determining the reference population to use in evaluating the likelihood of a match? If the defendant is Native American, for example, is the relevant subgroup all Native Americans or the specific sub-subgroup of Native Americans to which the defendant belongs? Some courts have been persuaded that the statistical estimation must be subgroup sensitive. But the logic of this conclusion is not obvious. Professor David Kaye provides a straightforward statement of the correct principle: "The relevant population consists of all people who might have been the source of the evidence sample."[59] As Professor Kaye observes, "In most cases, this will not be people with a defendant's ancestry, but people of many ethnic groups."[60] But this will not always be the case. As Professor Kaye notes, "Cases do arise where the population of interest is, arguably, a genetically distinct subpopulation, and where little or no data specific to that subpopulation have been collected."[61] In effect, the standard remains the same in all DNA

58. For an excellent discussion of this issue, see *id.* at 127-51.

59. *Id.* at 137-38. As an example of court confusion on this matter, Professor Kaye discusses *People v. Mohit*, in which "the court was concerned that the race and ethnicity of the dentist accused of raping his patient was not represented in the FBI's database." The *Mohit* court observed as follows:

> The issue of inbreeding is of particular importance in this case. The defendant, Dr. Mohit, was born in the Iranian town of Shushtar. His ancestors over at least the past five generations were of Persian descent, all from the same town or a town close by. They are all of the Shiite Muslim religion. Dr. Mohit claimed that for religious reasons, and as a matter of tradition, inbreeding was very common in his family. He indicated that his maternal grandmother was the daughter of his father's great-grandparents. Marriage among first cousins was common in his town.

Kaye, *supra* note 56, at 138 (quoting People v. Mohit, 579 N.Y.S.2d 990 (Sup. Ct. 1992)). Professor Kaye criticizes the *Mohit* court's analysis:

> The issue, however, is not the frequency of matching DNA patterns for inbred families of Shiite muslims from Shushtar, Iran, but their frequency in the vicinity of Westchester County, New York, or, more precisely, their frequency among people other than Dr. Mohit who might have left their semen on the patient. Unless this group consists largely of Dr. Mohit's relatives, there is no need to estimate the frequency among people of his racial and ethnic background. The frequency among broadly defined racial and ethnic groups is the apposite figure.

Kaye, *supra*, note 56, at 138-39.

60. *Id.* at 138.

61. *Id.* at 139. Professor Kaye provides the example of United States v. Two Bulls, 918 F.2d 56 (8th Cir. 1990), *vacated for reh'g en banc but appeal dismissed due to death of defendant*, 925 F.2d 1127 (1991):

> Accused of raping a girl on the Pine Ridge Indian reservation in South Dakota, Matthew Two Bulls moved to suppress testimony of a match between DNA ex-

cases—the reference population refers to the group from which the perpetrator must have come—but in some cases this group will be sufficiently homogeneous that it constitutes a narrow subgroup that must be used to calculate the probability of a "DNA match."

Courts must determine first, as a general matter, the principle for identifying the appropriate reference population and second, in the individual case, the population that should be considered in generating the likelihood of a match under the applicable standard. These two issues illustrate the respective strengths of trial and appellate courts. The appellate court possesses the advantage of a bird's-eye view by which to craft a standard applicable to a wide array of cases, whereas the trial court has the benefit of a close-up view by which to apply that standard to the peculiar circumstances of the case. An appellate court reviewing a trial court's rulings on these matters should bring a de novo standard to the issue of the appropriate standard, but should give deference when reviewing the application of the correct standard to the individual case. Similar dichotomies can be found in virtually every legal context in which scientific evidence is used.

(2) Ignorance of Science: The Peril of the Necessity Principle

This Essay began by discussing the scope of the challenge presented by *Daubert.* On the one hand, judges do not have the inclination or time to become so expert in science that they could contribute meaningfully to scientific debates; judges do not sit to resolve debates among scientists. On the other hand, judges must develop sufficient mastery of science to exert control over the admission of scientific evidence; judges do sit to protect the integrity and fairness of the trial process. Attaining a sophisticated and critical knowledge of the methods of science will not be easy and will require substantial investment of energy and resources. Over the next ten years, *Daubert's* success will be measured largely on the ability of lawyers and judges to learn the elements of science. Over this time, as was true in the past, there will be great temptation to slough off responsi-

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> tracted from semen on her underwear and his DNA. The FBI estimated the frequency of the matching pattern in "a Native American population base." However, the appropriate reference population is not all Native Americans, but only the Oglala Sioux. If the FBI's "Native American" database is an amalgam of distinct subpopulations while the suspect population is dominated by one subpopulation, the frequency of matches in the FBI's database might be beside the point.

Kaye, *supra*, note 56, at 139 (footnotes omitted).

bility for evaluating science, either to the multitude of witnesses-with-degrees who claim status in the scientific community or to jurors.

The necessity principle contains the danger of contributing to this practice. Because it permits the evaluation of science within a broader legal context, there might appear to be less certainty and control of scientific evidence. In one respect, this is true. Employed by the scientifically illiterate, the necessity principle poses the danger of opening the courthouse door to a variety of sorcery. As judges and lawyers begin to more fully appreciate the subtleties of science, legal decisions will begin to be more subtle themselves. The simple black and white categories of good and bad science will evolve into a spectrum containing many shades of gray. In order to appreciate and operate this system, judges will need to be able to distinguish between these shades of gray. The peril lies with those judges who, for convenience sake, see gray in black or white.

The necessity principle might contribute to judicial myopia by permitting judges to relax demands for scientific validity on the ground of jurisprudential need. Such need might continue indefinitely with uncritical judges failing to demand that scientists fully test their theories. In this way, necessity becomes an avenue by which bad science continues to be employed because it is all that is available to answer the scientific questions the law asks. But this distorts the necessity principle, which is based on the central premise that judges understand the culture of science. And the core tenet of this culture is rigorous testing of hypotheses.

Although the necessity principle contains within it the very seed that might destroy *Daubert,* the promise it offers for a mature science and law relationship is worth the risk. Indeed, without some version of the necessity principle, *Daubert* might not be worth saving. Without the necessity principle, courts will continue to interpret scientific research in a vacuum that fails to account for the demands of the legal context. Only by fully appreciating the nature of the legal issues presented together with the strengths and limitations of the pertinent scientific evidence can law and science be integrated into a seamless harmony.

Conclusion

As judges begin the task of reviewing scientific evidence under the validity standard articulated in *Daubert,* many questions arise concerning its practical application. Foremost, perhaps, judges might be concerned with how wide and deep their knowledge of science must be in order to implement *Daubert.* In addition, because *Daubert's* validity standard rests squarely on the traditional evidentiary principle of trustworthiness, it remains unclear how other traditional principles, such as necessity, interact with *Daubert.* In large measure, these two issues are closely tied, for they both concern, in general, judges' facility with scientific concepts and, more particularly, their ability to integrate those concepts into the law.

This Essay proceeds on the assumption that *Daubert* requires judges to become sophisticated consumers of science. However, as consumers, judges need not themselves be scientists. The scientific sea is enormously wide and deep, and judges cannot be expected to be steeped in the detail of all of the science that comes before them. At the same time, although judges need not be expert enough to write scientific articles, they should be proficient enough to read them. Such proficiency would entail judges having a basic knowledge of statistics and research methodology.

A substantial level of sophistication in the scientific method will be necessary if judges are ever going to integrate science successfully into their legal decisions. *Daubert* rests on the notion of scientific validity. But science does not come conveniently prepackaged into valid and invalid containers. Scientific findings inevitably contain the possibility of error, either as a statistical matter or because of the limitations of the research methods used. When making admissibility determinations, judges must consider the possibility of error in light of the jurisprudential necessity for the evidence. This Essay outlines a perspective whereby a judge's determination regarding admissibility would be a product of both scientific validity and jurisprudential need. This necessity component would be a function of the legal context together with the judge's evaluation of the scientific field's testing of the matter. The necessity principle fully weds the state of the art of the science to the legal context in which that science is relevant.

As judges begin to plunge into the scientific sea in an effort to learn enough to stay afloat, they will find that it is a rough and sometimes inhospitable environment. But with practice and patience they should find that, despite the coldness of the waters, science contains a world of immeasurable value to the law. All that remains to discover this world is for judges to hold their noses, open their eyes, and jump.